Transmit Diversity applied on the CDMA/TDD Cellular Systems

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Abstract This paper shows that the result of cell search and Open Loop Transmit Divesty of CDMA TDD. The TSTD type transmit diversity for PSCH can shorten the cell search time of UE at low Doppler frequency. The Block STTD type transmit diversity for P-CCPCH can improve the BER performance around 3dB compared with a single antenna transmission. Furthermore the authors propose open loop type sector/cell selection handover. The improvement by using this scheme, as compared to hard handover, is almost 2 dB for between sectors and 1.1dB to 1.6dB for between cells, depending on Doppler frequency. The change for the switching rate into 10ms makes the gain of 0.8dB at f_D=53Hz and 1.7dB at f_D=222Hz, respectively.

I. Introduction

The CDMA(Code Division Multiple Access) is a key multiple access technologies proposed for IMT-2000 being standardized in ITU-R. CDMA based system is categorized as follows[1]: CDMA DS(Direct Sequence) and CDMA MC(Multi Carrier), which access method is FDD (Frequency Division Duplex), and CDMA TDD(Time Division Duplex)[1]. CDMA TDD is based on TD-CDMA (Time Division-Code Division Multiple Access)[2,3] system and W-CDMA/TDD (Wideband-Code Division Multiple Access)[2,4], which introduces beneficial schemes using channel reciprocity of TDD[5,6]. Narrow band (1.28Mcps) of TDD is based on TD-SCDMA[2,7]. The authors have proposed CDMA TDD cellular system[8,9] and proved transmit diversity on Base station (BS) and open loop transmit power control (OL-TPC) on User Equipment (UE) through field trials.

In this paper, we propose three techniques using channel reciprocity of TDD.

(1) Transmit diversity for Synchronization Channel
BS transmits a Physical Synchronization Channel from 2 antennas alternatively. Initial synchronization acquisition time on the UEs is shortened due to both time and space diversity.

(2) Transmit diversity for Common Control Channel to enhance OL-TPC reference
BS transmits a Primary Common Control Channel (P-CCPCH), that is a reference of OL-TPC on the UE, from both antennas using Block STTD (Space Time Transmit Diversity) encoding. OL-TPC accuracy is improved due to space diversity. Besides that, intra- and inter-cell interference from UE is also reduced.

(3) Open Loop Sector/Cell selective Handover
On the CDMA TDD system, the slot must be switched to another for performing handover since the reuse is not 1. To reduce the power consumption on UE, we propose an open-loop sector/cell selective handover based on the receive power of the common control channel. When switching a cell to another, the size of the interleave is reduced from 20ms to 10ms to improve the switching rate.

II. Configuration of the CDMA TDD mode

A. System Description

Table 1 shows the main specification of CDMA TDD system. Figure 1 shows the frame format[10] for chip rate of 3.84Mcps. Frame format of low chip rate (1.28Mcps) is for further study at this moment. Figure 2 shows the transport channel to physical channel mapping[6].

Table 1 Main specifications of CDMA TDD mode system

Items	Specification
Access Method	DS-CDMA TDD (with TDMA Component)
Frequency Band width	5 [MHz]
Chip Rate	3.84 [Mcps] / 1.28 [Mcps]
Frame Structure	See Figure 1
Data/Spreading Modulation	Data: QPSK , Spreading: $\pi/2$ shift BPSK
Scrambling	16 chip
Channelization Code	OVSF (1-16)
Training Sequence	Midamble (512/256 [chip])
Error Correction	Convolutional (K=9, R=1/2) or Turbo code
Power Control	Uplink: Open Loop + Outer Loop Downlink: Inner Loop + Outer Loop
Inter-BS synchronization	Synchronization
Transport Channel to Physical Channel mapping	See Figure 2

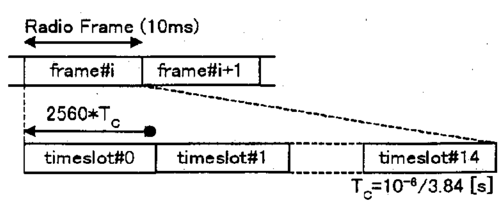

Figure 1 Frame Format for 3.84Mcps

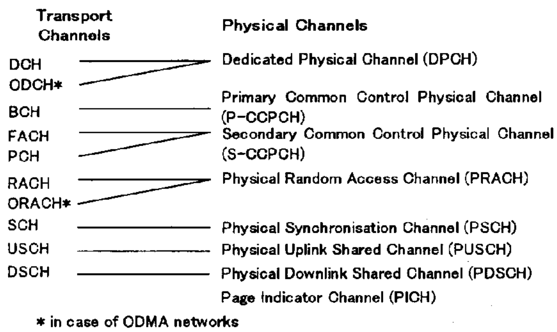

Figure 2 Transport channel to physical channel mapping

B. Cell Search and Synchronization Channel

The Synchronization Channel (Figure 3) is used for Cell Search on UE. The SCH consists of two sub channels, the Primary and Secondary SCH. The Primary SCH consists of the Primary Synchronization Codes, a modulated code of length 256 chips, which is transmitted in one or two slots in every Radio Frame. The Secondary SCH consists of a length 15 repeatedly transmitted Secondary Synchronization Codes, which is a sequence of modulated codes of length 256 chips. This initial cell search is carried out in three steps.

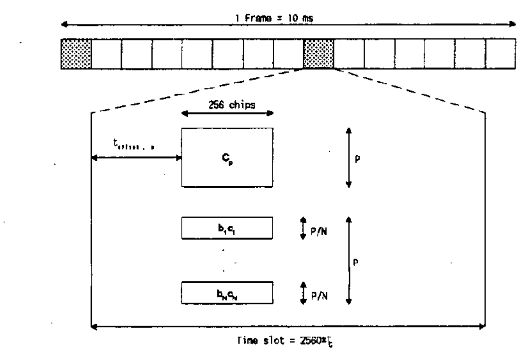

Figure 3 Scheme for Physical Synchronisation channel (PSCH)

C. Transmit Diversity Schemes[11]

Transmit diversity schemes for the CDMA TDD system are as follows.

(1) Physical Synchronization Channel (PSCH)

Time Switched Transmit Diversity (TSTD) is applied to PSCH. Figure 4 shows the antenna switching pattern. P-SCH and S-SCH are transmitted from antenna 1 and 2 alternatively.

(2) Primary-Common Control Channel (P-CCPCH)

Block Space Time Transmit Diversity (Block STTD) may be employed as transmit diversity scheme for the P-CCPCH. A block diagram of the Block STTD transmitter is shown in Figure 5 Before Block STTD encoding, channel coding, rate matching, interleaving and bit-to-symbol mapping are performed in the non-diversity mode. Block STTD encoding is separately performed for each of the two data fields present in a burst. For each data field at the encoder input, 2 data fields are generated at its output, corresponding to each of the diversity antennas.

(3) Dedicated Physical Channel (DPCH)

Selective Transmit Diversity (STD) and Transmit Adaptive Antennas (TxAA) are examples for DPCH. The transmitter structure is shown in Figure 6. The spread complex valued signal is fed to both transmit antenna branches, and weighted with antenna specific weight factors w_1 and w_2. The weight factors are complex valued signals (i.e., $w_i = a_i + jb_i$), in general. These weight factors are calculated on a per slot and per user basis.

The weight vector of STD will take only two values depending on the signal strength received by each antenna in the uplink slot. For each user, the antenna receiving the highest power will be selected.

The weight vector for TxAA to be applied at the transmitter is the w that maximises:

$$P = \mathbf{w}^H \mathbf{H}^H \mathbf{H} \mathbf{w} \qquad (1)$$

where

$H=[h_1 \ h_2 \ldots]$

and where the column vector h_i represents the estimated uplink channel impulse response for the i'th transmission antenna, of length equal to the length of the channel impulse response.

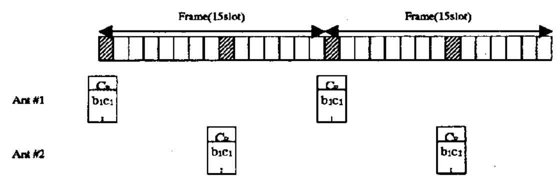

Figure 4 Transmit Diversity applied to PSCH

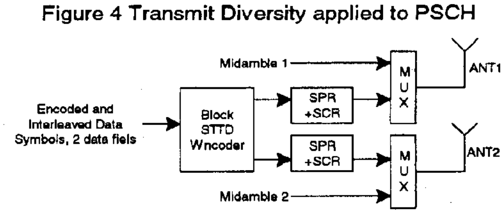

Figure 5 Transmit Diversity applied to P-CCPCH

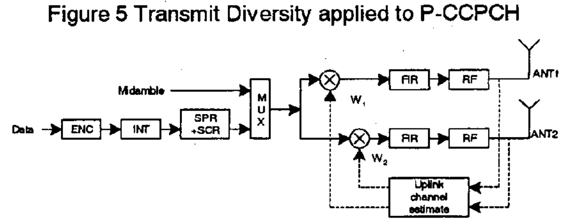

Figure 6 Transmit Diversity applied to DPCH

D. Transmit Power Control

Power control is applied for the TDD mode to limit the interference level within the system thus reducing the intercell interference level and to reduce the power consumption in the UE.

Table 2 Transmit Power Control characteristics

	Power control rate	Step size
Uplink	Variable 1-7 slots delay (2 slot SCH) 1-14 slots delay (1 slot SCH)	
Downlink	Variable, with rate depending on the slot allocation.	1, 2, 3 dB

(1) Uplink Control

For CPCH, the transmitter power of UE shall be calculated by the following equation:

$$P_{PRACH} = L_{P\text{-}CCPCH} + I_{BTS} + C \qquad (2)$$

where

- P_{PRACH} Transmitter power level in dBm,
- $L_{P\text{-}CCPCH}$ Measure representing path loss in dB (reference transmit power is broadcast on BCH),
- I_{BTS} Interference signal power level at cell's receiver in dBm, which is broadcast on BCH,
- C This constant value shall be set by higher Layer (operator matter).

For DPCH, after the synchronization between UTRAN and UE is established, the UE transits into open-loop transmitter power control. The transmitter power of UE shall be calculated by the following equation:

$$P_{UE} = \alpha L_{P\text{-}CCPCH} + (1-\alpha)L_0 + I_{BTS} + SIR_{TARGET} + C \quad (3)$$

where

- P_{UE} Transmitter power level in dBm,
- $L_{P\text{-}CCPCH}$ Measure representing path loss in dB (reference transmit power is broadcast on BCH).
- L_0 Long term average of path loss in dB
- I_{BTS} Interference signal power level at cell's receiver in dBm, which is broadcast on BCH
- α α is a weighting parameter which represents the quality of path loss measurements. α may be a function of the time delay between the uplink time slot and the most recent down link time slot containing a physical channel that provides the beacon function.
- SIR_{TARGET} Target SNR in dB. A higher layer outer loop adjusts the target SIR.
- C This constant value shall be set by higher Layer (operator matter).

If the midamble is used in the evaluation of $L_{P\text{-}CCPCH}$ and L_0, and the Tx diversity scheme used for the P-CCPCH involves the transmission of different midambles from the diversity antennas, the received power of the different midambles from the different antennas shall be combined prior to evaluation of these variables.

(2) Downlink Control

The Primary CCPCH transmit power can be changed based on network determination on a slow basis. The reference transmit power of P-CCPCH is signaled on the BCH on a periodic basis.

For Dedicated Physical Channel, the initial transmission power of the downlink Dedicated Physical Channel is set by the network. After the initial transmission, the UTRAN transits into SIR-based inner loop TPC.

III. Evaluation results

A. Cell Search with Transmit Diversity

The simulation assumed the 19 hexagonal cell layout shown in Figure 7. A cell site is located at center of each cell. We generated a random location of the test UE at a cell edge. This simulation condition was tight because of the weaker desired signal power and larger other-cell interference.

The simulation results on the first step of cell search are shown in Figure 8 (parameter is E_b/N_0) and Figure 9 (parameter is C/PG). We can clearly understand that the introduction of TSTD scheme for PSCH can significantly shorten the search time more than fixed antenna scheme at low maximum Doppler frequency f_D because of transmit diversity gain.

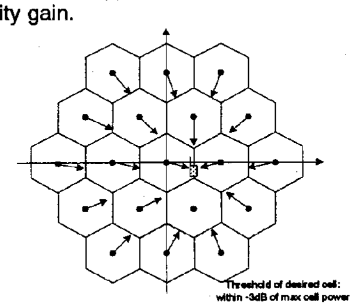

Figure 7 Cell layout (cell radius = 2km)

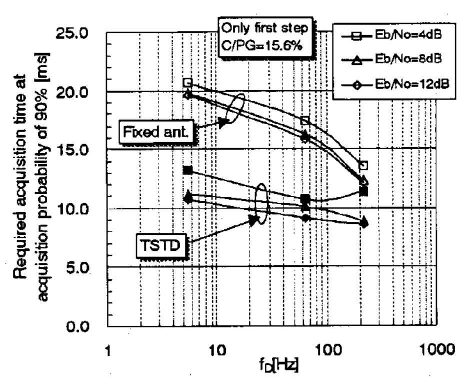

Figure 8 Simulation results of first step on cell search (Parameter: Eb/N0)

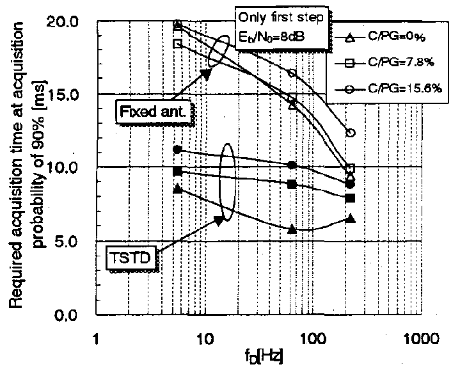

Figure 9 Simulation results of first step on cell search
(Parameter: C/PG)

B. Uplink Transmit Power Control with Transmit Diversity

To measure path loss, the UE receives a Midamble of P-CCPCH, which is transmitted from 2 antennas on BS alternatively, and combines them. Then the UE estimates both long term and short term path loss using reference transmit power that is broadcast on BCH. After that, the UE calculates transmit power using equation (3). Table 3 shows the simulation parameters. From Figure 10, OL-TPC gain using P-CCPCH with Block STTD (diversity scheme) on single antenna at BER of 10^{-3} is 3dB under one user environment. Figure 11 shows a BER performance of OL-TPC using Joint Detection[12] under 4 users environment. OL-TPC gain of measuring path loss using parallel transmitted Midamble to single antenna at BER of 10^{-3} is 3dB.

Table 3 Simulation Parameters

items	Parameters
Doppler Frequency	52.8Hz
Path model	equal level 2 path (1chip delay)
FEC	Convolutional Code (K=9,R=1/2)

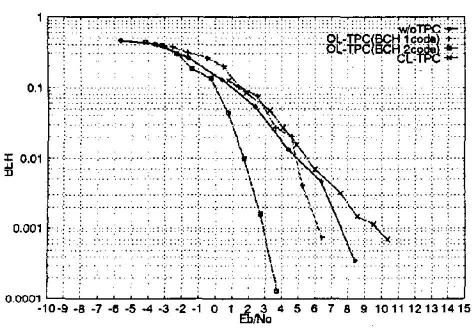

Figure 10 Uplink BER performance
(1 User using RAKE receiver)

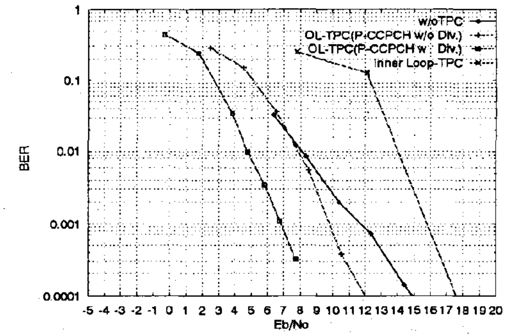

Figure 11 Uplink BER performance
(4 user using Joint Detection[12])

IV. Additional Proposals

A. Open Loop Sector/Cell Selection Diversity

On the CDMA TDD system, the slot must be switched to another for performing handover since the reuse is not 1. It is necessary to use two slots to realize diversity handover, which increases the power consumption of UE. Therefore, it is intended to secure performance and reduce power consumption by receiving signals through the common control channel for two or more base stations on the UE side during handover, and by selecting the best destination of transmission. The transmission power is controlled for the selected destination of transmission. For Maximum Ratio Combining can be employ as diversity scheme on handover between sectors, selection is performed in steps of 10ms. Since the voice service of the CDMA TDD implements 20ms interleave, selection is performed in steps of 20ms for handover between cells. We therefore propose that 10ms interleave be employed during handover between cells. Table 4 shows the handover scheme.

Table 4 Handover scheme

Scheme		Handover between sectors	Handover between cells
1	UE transmission	Hard handover	Hard handover
	BS receiving	Hard handover	Hard handover
2	UE transmission	Selects the sectoe in steps of 10ms 20ms interleave	Selects the sector in steps of 20ms 20ms interleave
	BS receiving	Maximum-ratio combining	Selective
3	UE transmission		Selects the sector in steps of 10ms 10ms interleave
	BS receiving		Selective
4	UE transmission	Transmits to both the slots 20ms Interleave	Transmits to both the slots 20ms Interleave
	BS receiving	Maximum-ratio combining	After performing the maximum-ratio combining in the cell, performs selection between the cells

(1) Handover between sectors

The simulation result is given in Figure 12 and Figure 13. When using Time Slot (TS) #1,2 instead of hard handover (a), the required E_b/N_0 can be reduced by about 1dB through transmission by switching the two sectors (b). Compared with transmission to both the sectors (transmission power is increased by 3dB), the required E_B/N_0 for f_D<53Hz is reduced by about 1dB. At 222Hz where the effect of the open-loop selective diversity is lost, the difference is 3.5dB. This shows that the operation is favorable under the Doppler frequency environment at a speed lower than the medium speed. Almost the same result is obtained when using TS#5,6 in Figure 13.

(2) Handover between the cells

The simulation result is given in Figure 12 and Figure 13. When comparing handover between the cells (a, c, d, and f) with hard handover. The required E_b/N_0 can be reduced by about 1.1 to 1.6 dB through transmission by switching the two cells (a, d). Compared with sending to both the cells (transmission power is increase by 3dB), the required E_b/N_0 becomes -0.4 to -1.6 dB at f_D<53Hz and -6.0 dB at f_D=222Hz. This shows that the operation is favorable under the Doppler frequency environment at a speed lower than the medium speed. As for the case where the size of the interleave is changed to 10ms in order to obtain the switching rate of 10ms, the gain of required E_b/N_0 becomes 0.8dB at f_D=53Hz and 1.7dB at f_D=222Hz, respectively. This result shows that the change for the switching rate into 10ms is effective during handover between cells.

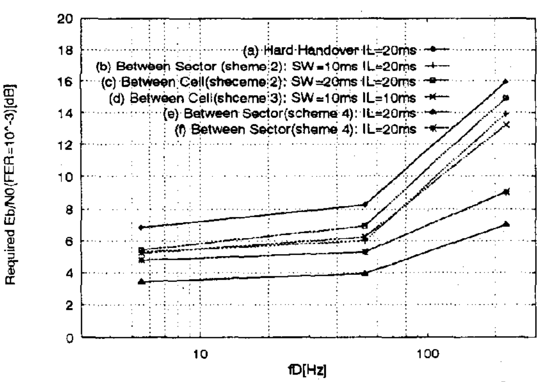

Figure 12 Uplink FER performance of Open Loop Sector/Cell Selective Handover (TS#1,2)
(SW: Switching rate/ IL: Inter leaving size)

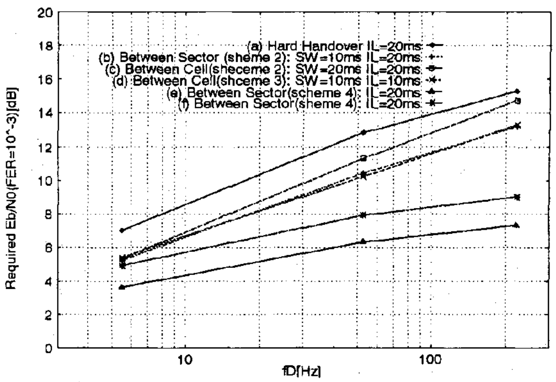

Figure 13 Uplink FER performance of Open Loop Sector/Cell Selective Handover (TS#5,6)

IV. Conclusions

In this paper, we proposed transmit diversity for PSCH an d P-CCPCH. The TSTD type transmit diversity for PSCH can shorten the cell search time of UE at low Doppler fre quency. The Block STTD type transmit diversity for P-CC PCH can improve a BER performance around 3dB comp ared with a single antenna transmission. Furthermore we proposed open loop type sector/cell selection handover. T he improvement by using this scheme, as compared to h ard handover, is almost 2 dB for between sectors and 1.1 dB to 1.6dB for between cells, depending on Doppler freq uency. The change for the switching rate into 10ms make s the gain of 0.8dB at f_D=53Hz and 1.7dB at f_D=222Hz, re spectively.

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